

## PATENT ABSTRACTS OF JAPAN

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**(54) ALUMINUM ALLOY FOR INTERNAL COMBUSTION ENGINE PISTON EXCELLENT IN HIGH TEMPERATURE STRENGTH AND ITS PRODUCTION**

**(57)Abstract:**

**PURPOSE:** To produce an aluminum alloy for a piston improved in high temp. strength.  
**CONSTITUTION:** This aluminum alloy for an internal combustion engine piston has a compsn. contg. 3 to 7% Cu, 8 to 13% Si, 0.3 to 1.0% Mg, 0.1 to 1.0% Fe, 0.01 to 0.3% Ti, 0.001 to 0.01% P and 0.0001 to 0.01% Ca, contg., at need, 0.2 to 2.5% Ni, and in which P/Ca is regulated to the range of 0.5 to 50 by weight ratio. This alloy is subjected to solution treatment of casting at  $\leq$  20° C/sec cooling rate and heating to 480 to 510° C for 3 to 10hr, is subjected to aging treatment of hardening in hot water and heating to 160 to 230° C for 2 to 10hr and is subsequently machined to form into an objective shape. By refining primary crystal Si and promoting the growth of eutectic Si, its excellent wear resistance is maintained, and its high temp. strength can be improved.

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CLAIMS

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[Claim(s)]

[Claim 1] Cu: The aluminium alloy for internal combustion engine pistons which was excellent in the high temperature strength by which P/calcium is adjusted to the range of 0.5–50 by the weight ratio including 3–7 % of the weight, Si:8–13 % of the weight, Mg:0.3–1.0 % of the weight, Fe:0.1–1.0 % of the weight, Ti:0.01–0.3 % of the weight, P:0.001 – 0.01 % of the weight, and calcium:0.0001–0.01 % of the weight.

[Claim 2] Furthermore, the aluminium alloy for internal combustion engine pistons excellent in the high temperature strength containing nickel:0.2–2.5 % of the weight according to claim 1.

[Claim 3] The aluminium alloy for internal combustion engine pistons the mean particle diameter of a primary phase Si excelled [ aluminium alloy ] in 40 micrometers or less at the high temperature strength according to claim 1 or 2 in which the average length of eutectic Si has a cast structure 20 micrometers or more.

[Claim 4] The manufacture method of the piston made from an aluminium alloy for internal combustion engines which performs solution treatment heated at 480–510 degrees C for 3 to 10 hours after casting an aluminium alloy molten metal with composition according to claim 1 or 2 in the cooling rate of 20 degrees C/second or less, gives hardening and the aging treatment subsequently to 160–230 degrees C heated for 2 to 10 hours immediately to warm water, and is machined in a target configuration after carrying out air cooling.

[Claim 5] The piston for internal combustion engines manufactured by the method of a claim 4.

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[Translation done.]

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## DETAILED DESCRIPTION

### [Detailed Description of the Invention]

#### [0001]

[Industrial Application] this invention relates to the aluminium alloy excellent in the high temperature strength suitable as a piston included in internal combustion engines, such as a diesel power plant and a gasoline engine, and its manufacture method.

#### [0002]

[Description of the Prior Art] The hypereutectic aluminum-Si alloy which contains Si 12.6% of the weight or more has a small coefficient of thermal expansion, and is excellent in abrasion resistance. Moreover, in case a molten metal solidifies, in order that the primary phase Si of a high degree of hardness may crystallize, it is used as a piston of the internal combustion engine with which abrasion resistance is demanded. However, in order that a primary phase Si may grow greatly, it is inferior to machinability. With this point and a hypoeutectic aluminum-Si alloy, there is also crystallization of eutectic Si and an improvement of processability is also found. There is AC8A as a typical thing of a hypoeutectic aluminum-Si alloy. It is in the inclination to raise combustion efficiency from a deployment of an energy resource, in the latest internal combustion engine. If it is going to raise combustion efficiency, combustion temperature will rise, and the various parts built into the internal combustion engine in connection with this, especially a high temperature strength high as the quality of the material of a piston in the temperature region near 200 degree C are required.

[0003] As an aluminium alloy for pistons which has improved the high temperature strength, it is T5. The thing with a high temperature strength and a thermal shock resistance sufficient also by heat treatment is introduced by JP,57-79410,A. In this alloy, while regulating Si content in 8.5 – 13.5% of the weight of the range, eutectic Si is improved by Sb addition. Moreover, in JP,55-24784,A, the thermal shock resistance is improved with heat treatment which heats Fe system base material at 480–520 degrees C after casting for 1 to 8 hours when manufacturing an insert piston with a aluminum-Si-Cu-Mg alloy. Although an aluminum-Si alloy presents the abrasion resistance which originated and was excellent in the hard primary phase Si crystallizing, it tends to become the cast structure the primary phase Si grew up to be greatly. If it is processed in this state, a crack going into a primary phase Si, an interface with an aluminium matrix, etc., and the target product not only not being obtained but a mechanical property is not enough. Especially, there is a fault which galling resulting from a primary phase Si generates in the case of cutting. A primary phase Si turns minutely by the rapid solidification method. For example, a powder method is adopted, or the rapid solidification of the aluminium alloy molten metal is carried out by the molten-metal rolling-out method JP,52-129607,A sees, and detailed-ization of a cast structure is attained.

[0004] Also by doing P processing of an aluminium alloy molten metal, a primary phase Si can be made detailed. By P addition, a primary phase Si is turned minutely and the improvement of processability and a mechanical property is aimed at. Added P forms an intermetallic compound AlP and is considered that this intermetallic compound AlP acts on detailed-ization of a primary phase Si. For example, in JP,52-153817,A, hexametaphosphoric acid sodium and the fusion object of an alumina are added to an aluminium alloy molten metal, the segregation of a primary

phase Si is suppressed, and detailed-ization of a cast structure is attained. Moreover, in JP,60-204843,A, processing the hypereutectic aluminum-Si alloy which contains 16 – 25% of the weight of Si qualitatively [, such as a Cu-P alloy red phosphorus, a sodium phosphate, and calcium phosphate, ] of P inclusion is introduced.

[0005]

[Problem(s) to be Solved by the Invention] However, the method of detailed-izing of passing through an ingot like metal mold casting and DC casting is inadequate in many cases only at P addition, especially when using it as extrusion material, a forging, etc., the crack of the primary phase Si at the time of processing poses a problem. The operation of P addition which makes a primary phase Si detailed tends to be lost when an aluminum-Si alloy contains Na or calcium. this point — being related — for example, \*\*\*\*\* Foundation edit "the development research report (I) of the Showa highness silicon aluminium alloy die casting in the 59 fiscal year" — it is explained as follows by the 24-25th page Na and calcium which are contained in the aluminum-Si alloy react with P, Na-P and calcium-P are formed, and generation of AIP which acts on detailed-ization of a primary phase Si is barred. Therefore, P addition which aimed at detailed-ization of a primary phase Si was restricted to the hypereutectic aluminum-Si alloy with which the candidate for application, if possible, contains neither Na nor calcium.

[0006] calcium is an effective alloy element which presents the operation which improves eutectic Si and improves properties, such as the tractive characteristics of a hypoeutectic alloy, and an impact resistance value. However, in an aluminum-Si alloy, P checks an improvement operation of the eutectic structure by calcium conversely with checking an operation of P by which calcium is added for the formation of primary-phase Si detailed. Therefore, in the alloy of this system, when it is going to improve processability etc. by further detailed-ization of a primary phase Si, just P processing is inadequate and it cannot but depend on rapid solidification, such as the molten-metal rolling-out method which needs a special facility. this invention aims at offering the aluminum-Si alloy for pistons excellent in elevated-temperature nature, abrasion resistance, and processability by making the primary phase Si which fully turned minutely even if it was the method of passing through an ingot like metal mold casting and DC casting with control of a P/calcium ratio crystallize by being thought out that such a problem should be solved, and adjusting components, such as Cu, Si, Mg, Fe, and Ti, interrelatively.

[0007]

[Means for Solving the Problem] The aluminium alloy for internal combustion engine pistons of this invention is characterized by adjusting P/calcium to the range of 0.5-50 by the weight ratio including Cu:3-7 % of the weight, Si:8-13 % of the weight, Mg:0.3-1.0 % of the weight, Fe:0.1-1.0 % of the weight, Ti:0.01-0.3 % of the weight, P:0.001 – 0.01 % of the weight, and calcium:0.0001-0.01 % of the weight in order to attain the purpose. This aluminium alloy can also contain nickel:0.2-2.5 % of the weight further. The aluminium alloy for internal combustion engine pistons according to this invention performs solution treatment heated at 480-510 degrees C for 3 to 10 hours after casting an aluminium alloy molten metal with the composition mentioned above in the cooling rate of 20 degrees C/second or less, and after giving and carrying out air cooling of hardening and the aging treatment subsequently to 160-230 degrees C heated for 2 to 10 hours to warm water immediately, it is manufactured by machining in a target configuration. The mean particle diameter of a primary phase Si is 40 micrometers or less, and, as for the organization after casting, the average length of eutectic Si has become 20 micrometers or more.

[0008] Hereafter, the alloy element contained in the aluminium alloy of this invention, its content, etc. are explained.

Cu: Three to 7% of the weight, it is an alloy element effective in improvement in a high temperature strength and fatigue-at-elevated-temperature intensity, and the effect of Cu addition becomes remarkable in the state of dissolution. At less than 3 % of the weight, a high temperature strength runs short of Cu contents. However, if a lot of Cu(s) exceeding 7 % of the weight are contained, big crystallization objects, such as aluminum2 Cu, will generate at the time of casting, and it will become easy to generate a casting crack. Moreover, even if it adds Cu so much, the effect of the on-the-strength improvement corresponding to increase in quantity is not acquired, either.

Si: It is an indispensable alloy element used as eutectic Si effective in the improvement in 8 – 13 % of the weight abrasion resistance, and reduction of a coefficient of thermal expansion, and also present the operation which makes fluidity good. Moreover, it reacts with Mg which lives together and Mg<sub>2</sub> Si effective in an age-hardening is also generated. If Si content does not reach to 8% of the weight, alpha-aluminum serves as a subject, abrasion resistance and a high temperature strength will fall and a coefficient of thermal expansion will become large. On the contrary, in Si content exceeding 13 % of the weight, the size of a primary phase Si becomes large, and variance also increases. Consequently, the fall of the high temperature strength by stress concentration is caused.

[0009] Mg: Combine with Si 0.3 to 1.0% of the weight, and generate Mg<sub>2</sub> Si effective in an age-hardening. Unless Mg content reaches to 0.3% of the weight, sufficient aging operation is not obtained. On the contrary, in Mg content exceeding 1.0 % of the weight, at the time of casting, a lot of Mg<sub>2</sub> Si crystallizes and a mechanical property is reduced.

Fe: 0.1 to 1.0% of the weight, it is an alloy element effective in improvement in a high temperature strength, and is ineffective to it being remarkable by 0.1% of the weight or more of Fe content. Fe is crystallized as an intermetallic compound and improves the intensity in an elevated temperature. However, in Fe content exceeding 1.0 % of the weight, the intermetallic compound containing Fe turns into a big crystallization object which is hundreds of micrometers, and a high temperature strength is reduced on the contrary.

[0010] Ti: It is an alloy element effective when turning and homogenizing the quality of the material minutely about 0.01 – 0.3-% of the weight alpha-aluminum. If Ti content becomes 0.01% of the weight or more, alpha-aluminum will serve as a diameter of 10mm or less by macro crystal grain, and the effect by detailed-izing will become remarkable. However, in Ti content exceeding 0.3% of the weight, the big crystallization object of a aluminum-Ti system generates, and a mechanical property is degraded. Ti can be added as a detailed-ized agent of a Ti-B system. At this point, coexistence of 0.03 or less % of the weight of B is also permitted.

P: 0.001 – 0.01 % of the weight, and calcium: — 0.0001 to 0.01% of the weight, big and rough-ization of a primary phase Si is suppressed by coexistence of P and calcium, and high intensity is maintained. Moreover, eutectic Si becomes large and a wear-resistant improvement is achieved. However, calcium exceeding P exceeding 0.01 % of the weight or 0.01 % of the weight worsens fluidity nature, and makes a cast structure uneven.

[0011]: By the alloy system specified by this invention, it becomes the organization by which eutectic Si and a primary phase Si live together according to Si content, or a primary phase Si is hardly seen. Therefore in this invention, the performance demanded as a piston for internal combustion engines is in eutectic Si. Moreover, if a mean particle diameter is small even if a primary phase Si crystallizes, it will not have a bad influence on a high temperature strength, but the material which was excellent in abrasion resistance on the contrary will be obtained.

P/calcium(weight ratio): The size of 0.5 – 50 eutectic Si and a primary phase Si is controllable by the P/calcium weight ratio. Although this invention person etc. just introduced the operation by adjustment of a P/calcium weight ratio itself by the Japanese-Patent-Application-No. No. 244259 [ four to ] official report, Japanese Patent Application No. No. 161380 [ five to ], etc., if a P/calcium weight ratio does not amount to 0.5, the average length of eutectic Si will be set to less than 20 micrometers, and it will cause wear-resistant degradation. Conversely, in the P/calcium weight ratio exceeding 50, it originates in the increase in the amount of P, and the organization whose viscosity of a molten metal rose and was stable becomes is hard to be obtained.

[0012] Adjustment of a P/calcium weight ratio optimizes eutectic Si and the primary phase Si which are crystallized to a cast structure in relation to the alloy content as which the content was specified. P content, calcium content, and the P/calcium weight ratio which were specified by this invention are expressed in the field shown in drawing 1. Although the dotted line of drawing 1 is attached in order to explain the concept of this invention, and it is not completely quantitative, it is thought that near is displayed experimentally. By the alloy system specified by this invention, if Si content exceeds about 11 % of the weight, although it will depend also on the cooling rate at the time of casting, it becomes easy to crystallize a primary phase Si. If a primary

phase Si crystallizes in a second in 10–20 degrees C /by 10 – 11% of the weight of Si content and a cooling rate becomes annealing with a cooling rate of 10 degrees C [/second ] or less, a primary phase Si will crystallize by 11 – 12% of the weight of Si content. And if it becomes range \*\* of drawing 1 under the composition which a primary phase Si crystallizes besides eutectic Si, and cooling conditions, a primary phase Si will detailed-stop being able to turn easily. When this point and a primary phase Si crystallize, as P content, calcium content, and a P/calcium weight ratio are in field [ of drawing 1 ] \*\* – \*\*, it is necessary to adjust.

[0013] From an experimental result, the compound which works as a crystalline nucleus of a primary phase Si is imagined to be what is different as follows by field \*\* – \*\*. By field \*\*, a P–calcium system compound mainly becomes the crystalline nucleus of a primary phase Si at aluminum–P system compound and field \*\* by aluminum–P system compound and P–calcium system compound, and field \*\*. On the other hand, in field \*\*, since there are few aluminum–P systems and P–calcium system compounds, the operation which fully makes a primary phase Si detailed is not demonstrated. On the other hand, under conditions with few primary phases Si, i.e., a condition with few Si contents than near 11 % of the weight, Si crystallizes as eutectic. Therefore, the average length of eutectic Si becomes 20 micrometers or more anywhere in the field shown in drawing 1 . If it puts in another way, in P below straight-line D–C, and the amount of calcium, eutectic Si will turn into 20 micrometers or less minutely, and abrasion resistance will deteriorate. Therefore, the property demanded as a piston of an internal combustion engine is not satisfied. In order to maintain P content, calcium content, and a P/calcium weight ratio proper, a device is needed when ingotting an aluminium alloy molten metal. That is, since calcium is activity, it is tended to change a content, although P tends [ comparatively ] to remain in a molten metal. Then, calcium is added just before casting and calcium content of the alloy molten metal cast is maintained in the convention range.

[0014] nickel: It is the alloy element added if needed 0.2 to 2.5% of the weight, and improve the thermal resistance in near 200 degree C, and a high temperature strength. The effect of nickel addition becomes remarkable at 0.2 % of the weight or more. However, if a lot of nickel exceeding 2.5 % of the weight is included, elongation will fall and the fault which makes an aluminium alloy weak will appear. In the aluminium alloy according to this invention, Na, Mn, Zr, etc. may be included as other alloy elements. Na is an element mixed as an impurity, and since it presents the operation which makes eutectic Si detailed, it is desirable to set an upper limit to 20 ppm. When a Fe/Mn weight ratio is about 1, Mn makes a needlelike aluminum–Fe system compound massive, improves fluidity and fluidity nature, and acts effective in prevention of a HIKE nest. Zr can also be added by the Zr independent simultaneously [ it is effective in grain refining and / in 0.3 or less % of the weight of an amount ] with Ti.

[0015] Primary phase Si: A mean particle diameter is large in the size of a primary phase Si, and the high temperature strength of a 40-micrometer or less hypereutectic aluminum–Si alloy is influenced. To regulate the mean particle diameter of the upper shell which secures the high temperature strength to need, and a primary phase Si to 40 micrometers or less is needed. Eutectic Si: More than 20-micrometer hard eutectic Si has average length effective in a wear-resistant improvement. Such an effect will show up notably, if the average length of eutectic Si is set to 20 micrometers or more.

The cooling rate at the time of casting: In order to grow up eutectic Si into a 20-degree-C [ / ] or less second average length of 20 micrometers or more, it is required to set [ second ] up the cooling rate at the time of casting in 20 degrees C /or less. If a cooling rate exceeds a second in 20 degrees C /, it will be easy to crystallize eutectic Si with which average length does not fill 20 micrometers, and abrasion resistance will deteriorate. in addition, in this invention, metal mold casting and a forging cast process adopt — having — the base of a piston — it is cast by the profile In actual metal mold casting, the cooling rate of a molten metal is 3–4 degrees C/second a second at 8 degrees C /and a forging cast process.

[0016] Solution treatment: It is necessary to make Cu and Mg fully dissolve by the alloy system specified at 480–510 degrees C by the heating this invention for 3 to 10 hours. In solution treatment, when aiming at sufficient dissolution, it heats at 480–510 degrees C for 3 to 10 hours. At the elevated temperature at which heating temperature exceeds 510 degrees C, a burning

phenomenon appears and dissolution sufficient at the low temperature which does not amount to 480 degrees C cannot be aimed at. The effect by dissolution is saturated in 10 hours, and an improvement of a property is not found even if it applies the long time beyond it. On the contrary, heating of dissolution which is not filled in 3 hours is inadequate. Warm water hardening of the aluminium alloy after solution treatment is carried out. In water quenching, it is easy to generate a thing baking crack with many Cu contents.

Aging treatment: Mg2 Si deposits by the aging treatment with a heating temperature of 160 degrees C or more, and intensity of the alloy system specified at 160–230 degrees C by the heating this invention for 2 to 10 hours improves. However, in heating exceeding 230 degrees C, intensity falls on the contrary by overaging. In short-time heating which does not reach in 1 hour, even if an effect is small and heats exceeding 10 hours, the improvement corresponding to long time-ization is not found.

[0017]

[Example]

Example 1: The aluminium alloy molten metal which adjusted P content, calcium content, and the P/calcium weight ratio as shown in Table 1 was ingoted including Si:10.5 % of the weight, Cu:6.0 % of the weight, Mg:0.5 % of the weight, Fe:0.4 % of the weight, Ti:0.1 % of the weight, B:0.0006 % of the weight, Mn:0.4 % of the weight, Na:0.0004 % of the weight, and Zr:0.0001 % of the weight. Each aluminium alloy molten metal was cast from 760 degrees C to the JIS No. 4 brake-shoe type with the cooling rate of 8 degrees C/second. In addition, the cooling rate was adjusted by heating a brake-shoe type at 200 degrees C. After performing solution treatment of 500 degree-Cx 6 hours to the obtained ingot and burning in 60-degree C warm water, air cooling of the aging treatment of 220 degree-Cx 6 hours was given and carried out.

[0018]

[Table 1]

表1：アルミニウム合金溶湯のP含有量、Ca含有量及びP/Ca重量比

試験番号	P含有量	Ca含有量	P/Ca重量比	区分
1	10	30	0.3*	比較例
2	10	18	0.6	本発明例
3	20	10	2.0	"
4	50	5	10	"
5	60	3	20	"
6	80	2	40	"
7	120*	2	60*	比較例
8	15	20	0.8	"
9	50	20	2.5	本発明例

P含有量及びCa含有量の単位はppm

試験番号8、9のSi含有量は12.0重量%，他は10.5重量%

\*印は、本発明で規定した範囲を外れる値

[0019] From each alloy by which the aging treatment was carried out, the piece of an ordinary temperature abrasion test and the piece of an elevated-temperature tensile test were started by cutting. The elevated-temperature examination was aimed at the test piece after carrying out preheating to 200 degrees C for 100 hours. a friction wearing-of-die testing machine is used for an ordinary temperature abrasion test, it uses partner material as cast iron FCMP70, and is too heavy — it carried out under 50 kgf(s)/mm 0.23m/second in 2 and sliding speed, 3km of sliding distance, and the conditions of lubricant use A test result is combined with the size of a primary

phase Si and eutectic Si, and is shown in Table 2. Test numbers 1-7 show depending for the appearance of a primary phase Si on P content, calcium content, and a P/calcium weight ratio. That is, if there are few P contents and there are many calcium contents, the primary phase Si has stopped being able to appear easily. This is considered for the eutectic point to shift to right-hand side in an aluminum-Si state diagram. On the other hand, if there are many P contents, the eutectic point will shift to left-hand side, and the inclination for a primary phase Si to appear will become strong. This relation grows up eutectic Si greatly while it becomes entangled with a P/calcium weight ratio in multiplication and makes a primary phase Si detailed. Thus, in the test numbers 2-6 by which a primary phase Si and eutectic Si were reformed, it excelled in mechanical properties, such as tensile strength, 0.2% proof stress, and elongation, and abrasion resistance was also good. Its Si content was as low as 10.5 % of the weight, and since the cooling rate was slow, even if a primary phase Si hardly crystallized each alloy used by this example or moreover crystallized it, it was small or little. However, according to the P/calcium weight ratio, the average length of eutectic Si became large, elevated-temperature tensile strength rose with it, and abrasion loss fell rapidly. On the other hand, in the test number 1 of 0.3, the average length of eutectic Si had the P/calcium weight ratio as small as 15 micrometers, and abrasion loss also indicated the big value to be 240mg. In the test number 7 containing a lot of P, the viscosity of a molten metal rose, fluidity was bad and the cold shut occurred in the sample. In the test number 8 containing 12.0 % of the weight and a lot of Si, although the primary phase Si has crystallized, since P content and calcium content were in field \*\* of drawing 1, the detailed-ized effect over a primary phase Si was small, and the primary phase Si with a big mean particle diameter crystallized. As the result, the elevated-temperature tensile strength in 200 degrees C is falling. Although a test number 9 has the almost same composition as a test number 8, it is adjusting P content and calcium content to field \*\* of drawing 1. Consequently, a primary phase Si turns minutely and the elevated-temperature tensile strength which is 200 degrees C is also rising.

[0020]

[Table 2]

表2: 各合金の共晶Si, 初晶Si及び機械的特性

試験番号	共晶Si平均長さ(μm)	初晶Si平均粒径(μm)	200°C引張り試験			摩耗量 常温 (mg)	備考	区分
			$\sigma_s$	$\sigma_{0.2}$	$\delta$			
1	15*	-	232	211	2.0	240	初晶Si僅少	比較例
2	30	-	235	210	1.8	26	"	本発明例
3	35	30	240	215	1.6	9	初晶Si少量	"
4	42	15	247	224	1.4	8	"	"
5	50	13	245	220	1.3	8	-	"
6	49	12	245	218	1.2	9	-	"
7	-	-	-	-	-	-	湯流れが悪く	比較例
8	25	45*	220	216	0.6	7	湯塊発生	"
9	30	20	238	214	1.0	7	-	本発明例

・ $\sigma_s$  は引張り強さ (N/mm<sup>2</sup>),  $\sigma_{0.2}$  は2%耐力 (N/mm<sup>2</sup>),  $\delta$  は伸び(%)を表す。  
・\*印は、本発明で規定した範囲を外れることを示す。

[0021] Example 2: The aluminium alloy molten metal which adjusted P content, calcium content, and the P/calcium weight ratio as shown in Table 3 was ingoted including Si:10.5 % of the weight, Cu:6.0 % of the weight, Mg:0.5 % of the weight, Fe:0.4 % of the weight, Ti:0.1 % of the weight,

nickel:0.5 % of the weight, B:0.0005 % of the weight, Mn:0.4 % of the weight, Na:0.0003 % of the weight, and Zr:0.0001 % of the weight. Each aluminium alloy molten metal was cast under the same conditions as an example 1. After performing solution treatment of 500 degree-Cx 6 hours to the obtained ingot and burning in 60-degree C warm water, air cooling of the aging treatment of 220 degree-Cx 6 hours was given and carried out.

[0022]

[Table 3]

表3：アルミニウム合金溶湯のP含有量、Ca含有量及びP/Ca重量比

試験番号	P含有量	Ca含有量	P/Ca重量比	区分
10	10	30	0.3*	比較例
11	10	18	0.6	本発明例
12	20	10	2.0	〃
13	50	5	10	〃
14	60	3	20	〃
15	80	2	40	〃
16	120*	2	60*	比較例
17	15	20	0.8	〃
18	50	5	10	本発明例

P含有量及びCa含有量の単位はppm

試験番号17、18のSi含有量は12.0重量%，他は10.5重量%

\*印は、本発明で規定した範囲を外れる値

[0023] The mechanical property of each obtained alloy is combined with eutectic Si and a primary phase Si, and is shown in Table 4. Also in this case, the property eutectic Si and the primary phase Si excelled [ property ] in what was adjusted proper was shown. Moreover, the improvement of a high temperature strength was also achieved by nickel addition.

[0024]

[Table 4]

表4：各合金の共晶Si、初晶Si及び機械的特性

試験番号	共晶Si平均長さ(μm)	初晶Si平均粒径(μm)	200°C引張り試験			摩耗量 常温 (mg)	備考	区分
			$\sigma_s$	$\sigma_{0.2}$	$\delta$			
10	15*	-	234	212	1.8	210	初晶Si僅少	比較例
11	30	-	238	213	1.6	28	〃	本発明例
12	35	30	243	216	1.4	10	初晶Si少量	〃
13	42	15	250	227	1.3	8	〃	〃
14	50	13	247	223	1.1	7	〃	〃
15	49	12	247	220	1.0	7	〃	〃
16	-	-	-	-	-	-	湯流れが悪く	比較例
17	25	45*	223	217	0.4	6	湯境発生	〃
18	40	20	240	217	0.9	7	-	本発明例

\*  $\sigma_s$  は引張り強さ (N/mm<sup>2</sup>)、 $\sigma_{0.2}$  は2%耐力 (N/mm<sup>2</sup>)、 $\delta$  は伸び (%) を表す。  
\*印は、本発明で規定した範囲を外れることを示す。

[0025] Example 3: As shown in Table 5, the quality governing was carried out to Si:10.5 % of the weight, Cu:6.0 % of the weight, Mg:0.5 % of the weight, Fe:0.4 % of the weight, Ti:0.1 % of the weight, nickel:0 % of the weight, or 0.5% of the weight, the aluminium alloy molten metal (test numbers 19–24) it was made to become further B:0.0005 % of the weight, Mn:0.4 % of the weight, Na:0.0003 % of the weight, and Zr:0.0001 % of the weight was ingoted, and it cast from 760 degrees C to the JIS No. 4 brake-shoe type with The cooling rate heated the brake-shoe type at 400 degrees C, when near 2 degree C /was obtained a second, when near 8 degree C /was obtained a second, it heated the brake-shoe type at 200 degrees C, when near 15 degree C /was obtained a second, it heated copper mold at 150 degrees C, and when near 30 degree C /was obtained a second, it adjusted it by pouring cooling water to copper mold with water-cooled structure. Eutectic Si of each obtained alloy casting, a primary phase Si, a mechanical property, etc. are shown in Table 6. In the test numbers 21 and 24 with a cooling rate early in 30 degrees C/[ a second and ], although a P/calcium weight ratio is in a proper value, the average length of eutectic Si is short and abrasion loss is increasing. In the test number 25 of AC8A which added Na to 46 ppm of contents, since it originated in Na addition, and a primary phase Si was hardly seen but eutectic Si had also turned minutely, abrasion resistance was falling.

[0026]

[Table 5]

表5：使用したアルミニウム合金の種類と鋳造時の冷却速度

試験番号	合金成分及び含有量 (重量%)								P/Ca 重量比	溶浴の冷却速度 (°C/秒)	区分
	Si	Cu	Mg	Fe	Ti	Ni	P	Ca			
19	10.5	6.0	0.5	0.4	0.1	—	0.0050	0.0005	10	2	本発明例
20	10.5	6.0	0.5	0.4	0.1	—	0.0050	0.0005	10	15	〃
21	10.5	6.0	0.5	0.4	0.1	—	0.0050	0.0005	10	30*	比較例
22	10.5	6.0	0.5	0.4	0.1	0.5	0.0050	0.0005	10	2	本発明例
23	10.5	6.0	0.5	0.4	0.1	0.5	0.0050	0.0005	10	15	〃
24	10.5	6.0	0.5	0.4	0.1	0.5	0.0050	0.0005	10	30*	比較例
25	11.8	0.95	0.86	0.32	0.02	1.21	0.0014	0.0025	0.5	8	〃

・\*印は、本発明で規定した範囲を外れることを示す。

[0027]

[Table 6]

表6：各種アルミニウム合金の物性及び機械的特性

試験 番号	共晶Si 平均長さ (μm)	初晶Si 平均粒径 (μm)	200°C引張り試験			摩耗量 常温 (mg)	区分
			$\sigma_s$	$\sigma_{0.2}$	$\delta$		
19	60	25	235	220	0.8	5	本発明例
20	30	12	249	222	1.9	10	〃
21	17*	10	250	220	2.5	80	比較例
22	60	25	231	222	0.7	5	本発明例
23	30	12	253	225	1.7	10	〃
24	17*	10	250	221	2.2	75	比較例
25	<10*	-	187	159	4.1	300	〃

- ・  $\sigma_s$  は引張り強さ (N/mm<sup>2</sup>)
- ・  $\sigma_{0.2}$  は2%耐力 (N/mm<sup>2</sup>)
- ・  $\delta$  は伸び (%)
- ・ \*印は、本発明で規定した範囲を外れることを示す。

## [0028]

[Effect of the Invention] As explained above, this invention has turned the primary phase Si minutely while growing up eutectic Si greatly by adjusting P content, calcium content, and a P/calcium weight ratio in a aluminum-Si-Cu-Mg system alloy with the component and composition as which the content was specified. Thereby, a high temperature strength, abrasion resistance, etc. are improved and an aluminium alloy suitable as a piston of an internal combustion engine is obtained.

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[Translation done.]

**\* NOTICES \***

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2. \*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

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**DESCRIPTION OF DRAWINGS**

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[Brief Description of the Drawings]

[Drawing 1] The field specified by this invention is expressed with the graph of a P content-calcium content.

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[Translation done.]

**\* NOTICES \***

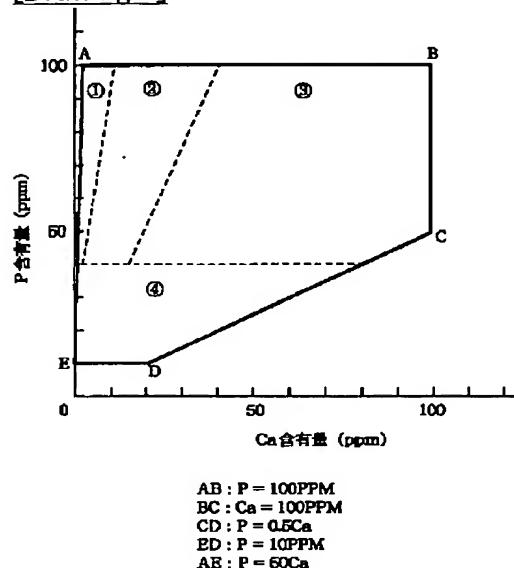
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**DRAWINGS**

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**[Drawing 1]**

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**[Translation done.]**

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